Featureless Tagging Tacking and Locating: Micromechanical Resonators

Sandia National Laboratories

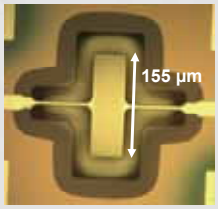
Rick Ormesher, Karen Branch, Jason Payne, Troy Olsson, Ken Wojciechowski, Chris Nordquist, Bob, Brocato, Jim Stevens, Peggy Clews, Melanie Tuck, Alex Bates, Collin Smithpeter and John Moser

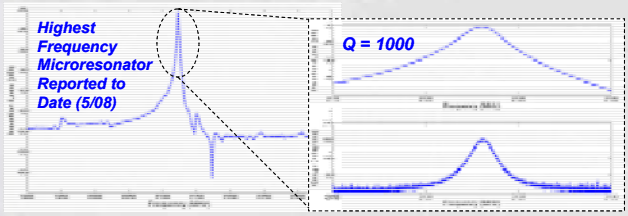
Problem

- The power consumption and size of an important class of TTL devices is limited by the lack of analog signal processing elements at X-band (~9 GHz).
- Commercial elements are limited in frequency to < 3 GHz, requiring extra circuitry for frequency conversion, which dominates the size and power consumption.
- Commercial elements also have high insertion loss (> 30 dB).
- Develop a low-loss, miniature analog signal processing element at X-band, enabling orders of magnitude reduction in TTL device size and power.

Approach

- Achieve X-band signal processor using micromechanical resonator delay element
- Requires record high-frequency operation
  - **Acoustic delays not available at X-band**
  - **Aluminum nitride microresonators**
    - High sound velocity (10 km/s, 3x > SAW)
      - *Can scale to higher frequency*
    - Low material damping (Q = 2000 @ 10 GHz)
      - *Low insertion loss*
- Requires order-of-magnitude higher bandwidth
  - **Requires new architecture to overcome fundamental k_t^2 barrier**
  - **Integrated inductors**
    - Resonates out shunt capacitance
    - Reduces insertion loss
    - Increases achievable bandwidth
    - Flattens delay response



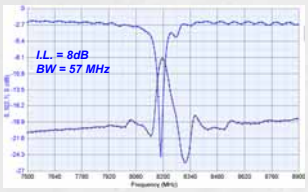


	Project Start	Scaled to X-Band GHz	Desired
f_0	2.1 GHz	9 GHz	**9 GHz**
Bandwidth	1 MHz	4.3 MHz	**50 MHz**
Delay	150 ns	35 ns	**20 ns**
Insertion Loss	20 dB	Unknown	**< 10 dB**

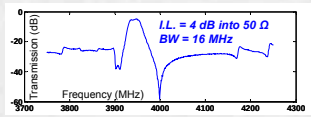
Pictures and table describing current state of the art at the project start and the desired performance

Results

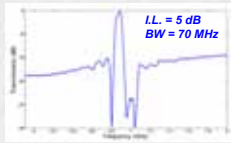
Microresonator Performance Scaling



8.3 GHz with integrated gold traces

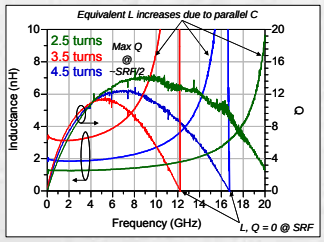


4-GHz filter based on new width extensional microresonator



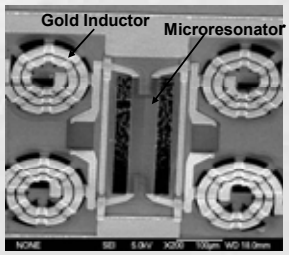
Improved AlN Allows Scaling to 7 GHz

	Start	4/09	10/09	8/10	2/11	Desired
f_0 (GHz)	2.1	3.95	6.9	8.2	13.3	X-Band
Bandwidth	2 MHz	16 MHz	70 MHz	57 MHz	42 MHz	50 MHz
Delay	150 ns	35 ns	7 ns	7 ns	12 ns	20 ns
Insertion Loss	20 dB	4 dB	5.2 dB	8 dB	8.5 dB	< 10 dB

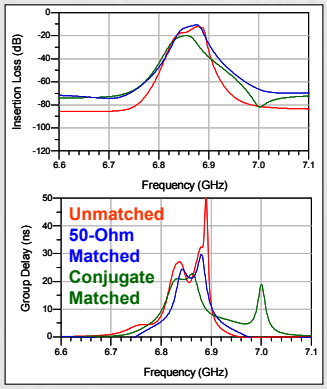


Measured Inductor Performance

Gold Matching Inductors Monolithically Integrated with Microresonators



Microresonator with Matching Inductors



Simulated Response of delay element currently under development with different matching

Integrated Delay Elements

- Projected performance for 50 Ω matched delay
  - 7 ns of delay/stage
  - 4 dB I.L./stage
  - 3 stages
    - *21 ns delay*
    - *12 dB I.L.*

Significance

Impact of Microresonator Technology

- Small, low-power TTL
- Real-time spectrum analysis and low-power signal processing
- Miniature, low -power oscillators

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

SAND 2010-5831P

Sandia National Laboratories